# Space-Time Secure Communications for Hostile Environments

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Communicating in a complex environment is a daunting problem. Such an environment can be a hostile urban setting populated with a multitude of buildings and vehicles, or military operations in an environment with obstructive topographic features, or even a maze of buried water pipes servicing a city. These inherent obstructions cause transmitted signals to reflect, refract, and disperse in a multitude of directions, distorting them at network receiver locations.

These are the communications problems we solve using wave propagation physics (see Fig. 1). We develop time-reversal (T/R) communications using sensor arrays in a hostile environment, incorporating theory, simulation and experiments.

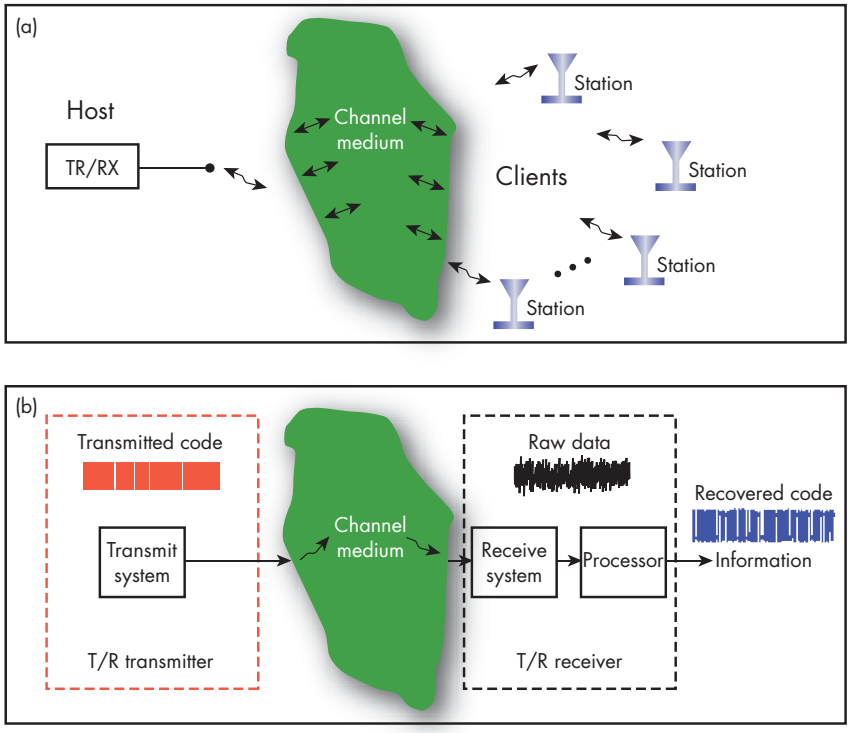


Figure 1. Representation of communications in a hostile environment: (a) the basic problem, including the host T/R, hostile medium, and client receiver stations; (b) T/R receiver solution, showing the transmitter, medium, and a particular T/R receiver structure extracting the coded information from the distorted received data.

## Project Goals

Successful development and demonstration of T/R receiver performance will lead to the next generation advance for military and defense applications, as well as potential commercialization. Ultimately, our success will provide improved communications in noisy, distorted environments, with a potential breakthrough technology for both military and civilian (commercial) applications. This effort is aimed at developing a core competency in wireless communication networks, and falls within the advanced sensor and instrumentation competency area.

## Relevance to LLNL Mission

Both the maintenance of communications in a strong multipath environment, and the protection of the communication against intercept, are important. Thus, there is a strong need for reliable channels in corrupting environments, with the additional feature that they be secure. Secure communications can be derived from T/R principles that will lead to novel applications, ranging from military applications (such as battlefield communications, urban warfare, tunnel complexes, and pipes) to the hostile urban environment. The T/R receiver technology also promotes protection of communication channels against intercept, and thus supports LLNL's national security mission as well as homeland defense applications.

## FY2004 Accomplishments and Results

In FY2004, we accomplished the following: 1) completed the theoretical development of T/R multichannel receivers; 2) developed an eight-element T/R array capability; 3) performed experimental designs validating multichannel T/R receiver designs; 4) demonstrated a critical

theoretical development for future electromagnetics (EM) experiments, using 1-bit A/D conversions for T/R receivers; 5) conducted controlled experiments demonstrating T/R receiver performance; 6) designed a highly scattering medium (on an aluminum plate); 7) investigated the development (hardware) for an EM receiver design; and 8) initiated spin-off DARPA projects using related T/R concepts and team members.

Figures 2 and 3 show our controlled experimental set-up and sample results.

### Related References


1. Candy, J., B. Guidry, A. Poggio, C. Robbins, and C. Kent, "Multichannel Time Reversal Communications in a Highly Reverberant Environment," *Journal of the Acoustical Society of America*, **115**, p. 2467, 2004.

2. Guidry, B., J. Candy, A. Poggio, A. Meyer, and C. Kent, "Experimental Design and Processing for Time-Reversal Communications in a Highly Reverberative Environment," *Journal of the Acoustical Society of America*, **114**, p. 2367, 2003.

3. Chambers, D., C. Kent, and A. Meyer, "Time-Reversal Communication Through a Highly Reverberant Medium," *Journal of the Acoustical Society of America*, **114**, p. 2468, 2003.

4. Chambers, D., J. Candy, S. Lehman, J. Kallman, and A. Poggio, "Time Reversal and the Spatio-Temporal Matched Filter," *Journal of the Acoustical Society of America*, **116**, p. 1348, 2004.

5. Candy, J., A. Meyer, A. Poggio, and B. Guidry, "Time-reversal Processing for an Acoustics Communications Experiment in a Highly Reverberant Environment," *Journal of the Acoustical Society of America*, **115**, pp. 1621-1631, 2004.


### FY2005 Proposed Work

We will continue developing a fundamental theoretical basis for T/R communications by pursuing both simulations and laboratory evaluations. Evaluation of the techniques in a hostile environment will lead to 1) theoretical development; 2) simulation-based evaluation of the benefits of T/R; 3) controlled laboratory validation of the simulation results; 4) an operational brass-board design of an actual T/R receiver for applications, using the 1-bit A/D concept; 5) development of new T/R principles using 1-bit A/D converters; and 6) participation in T/R communications experiments in wideband EM and acoustic-pipe experiments.

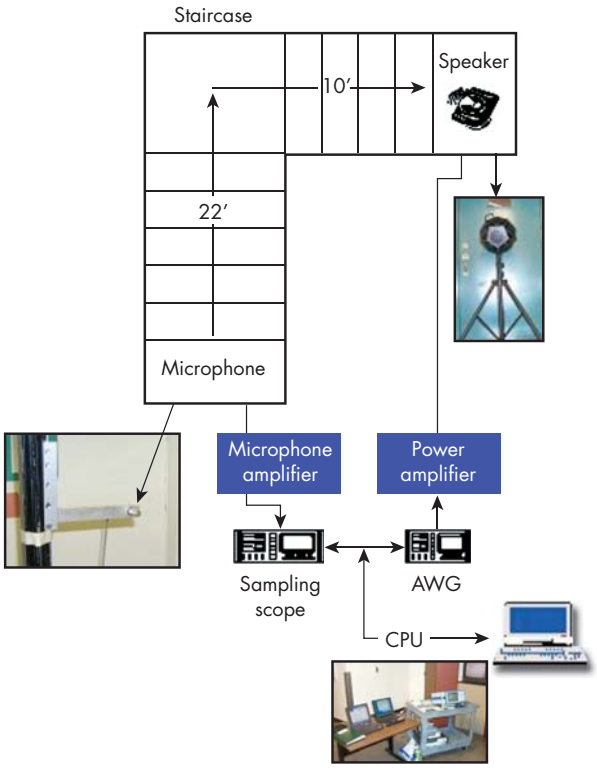


Figure 2. Controlled experimental set-up for T/R receiver designs: sound source (loud speaker), hostile medium (stairwell with obstructions), and microphone receiver with the T/R receiver implemented in software on the computer.

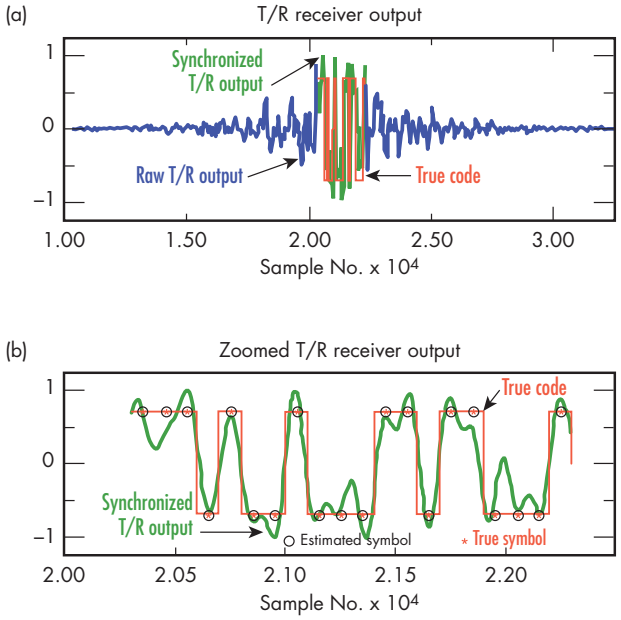


Figure 3. Time-reversal receiver output for the controlled stairwell experiment: (a) raw T/R receiver output, with synchronized code and true code superimposed; (b) zoomed synchronized T/R output, with both quantized code information extracted and true code superimposed. The estimated symbol and the true symbol are overlaid, demonstrating flawless T/R receiver operation.